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SPRAY SOLUTIONS AND THE CONTROL OF APPLE SCAB

By O. BUTLER *and* W. L. DORAN

THE UNIVERSITY OF NEW HAMPSHIRE

DURHAM, N. H.

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O. Butler and W. L. Doran

In the present paper we propose to study first the toxicity of lead arsenate, lime arsenate, lime-sulphur solution, and lime sulphur solution in combination with the arsenicals mentioned to the conidia *Venturia inaequalis* and the control of apple scab they have severally given in orchard spraying. We will then pass to a consideration of the effect upon the tree of the arsenicals mentioned both when used alone and in combination with lime-sulphur solution.

I

(a) LEAD ARSENATE. Morse[1] has more especially called attention to the value of lead arsenate for the control of apple scab. In 1913 he found that the non-sprayed trees produced approximately 39 per cent scabby apples, and that lead arsenate used at the rate of 2 lbs. to 50 gallons of water gave almost as satisfactory control of scab as 3-3-50 Bordeaux mixture. In 1914, a year of light scab infection, the trees sprayed with 2-50 lead arsenate produced about 3 per cent more scabby fruit than those sprayed with 1¼-50 lime-sulphur solution. In 1915 scab caused little or no injury, there being only 5 per cent scabby apples on the non-sprayed trees, and the control obtained with 2-50 lead arsenate was 12 times better than no spraying. In 1916 there were 38.81 per cent scabby apples on the non-sprayed trees and 1.61 per cent affected fruit on the trees sprayed with 2-50 acid arsenate lead; the protection afforded by lead arsenate was 24 times better than no spraying. In 1917, a year of severe scab infestation, the fruit on the non-sprayed trees was 98.37 per cent scabby and the fruit on the trees sprayed with 2-50 lead arsenate, 82 per cent scabby. In this instance the protection afforded by the lead arsenate was 1.2 times better than no spraying.

Pickett, Watkins, Ruth, Foglesong and Gunderson[2] found in one experiment that the trees sprayed with 2-50 lead arsenate produced 52 per cent scabby fruit and the non-sprayed trees 89 per cent; in other words the protection afforded by the lead arsenate was 1.7 times better than no spraying. In another experiment the non-sprayed trees yielded 89.36 per cent scabby fruit and the trees sprayed with lead arsenate 69 per cent. The protection afforded by the lead arsenate was 1.3 times better than no spraying at all.

[1]Morse, W. J. Six years' experimental spraying at Highmoor farm, Maine Agr. Exp. Sta. Bull. *249*: 1916.
———— Apple spraying experiments in 1915. Ibid Bull. *252*: 1916.
———— Apple spraying experiments in 1916 and 1917. Ibid Bull. *271*: 1918.
[2]Pickett, B. S., et al. Field experiments in spraying apple orchards. Illinois Agr. Expt. Sta. Bull. *185*: 1916.

Wallace[1] found in an experiment in which the non-sprayed trees produced 94.6 per cent scabby apples that the trees sprayed with lead arsenate 2-50 yielded 32 per cent scabbed fruit. The protection afforded by the lead arsenate was 3.2 times better than no spraying.

Morse and Folsom[2] have studied the value of acid and basic arsenates of lead for the control of scab. In 1918, 83 per cent of the apples on the non-sprayed trees were scabby whereas in the case of the trees sprayed with 2-50 acid arsenate of lead and 2-50 basic arsenate of lead there were produced respectively 49 and 44 per cent scabby fruit. The protection afforded by the basic arsenate of lead was 1.7 times better than no spraying and that given by the acid arsenate of lead was slightly but not significantly greater.

Laboratory tests made by Shapovalov, Morse[3] tells us, showed that the conidia of *Venturia inaequalis* were able to germinate in water containing 0.25 per cent lead arsenate, which would indicate that this salt is not a very active fungicide, and the field experiments as we have seen leave the matter in doubt.

How toxic is lead arsenate to the spores of *Venturia inaequalis*? The experiments of Shapovalov indicate that at the strength ordinarily used in orchard spraying lead arsenate is not toxic. Wallace, Blodgett and Hesler[4] found that lead arsenate did not possess any marked fungicidal properties. Spores of *Venturia inaequalis* sown in water gave 68 per cent germination and sown on slides previously sprayed with a 0.5 per cent solution of lead arsenate 35 per cent germination.

Following the technique of Reddick and Wallace[5] we have found, as will be seen from a consideration of the data presented in Table 1, that lead arsenate is not completely toxic even at the strength commonly used in practise, *i.e.*, 2-50.

TABLE 1.—*Toxicity of lead arsenate to the spores of Venturia inaequalis*

AMOUNT LEAD ARSENATE USED	CONIDIA GERMINATING
Per cent	*Relative numbers*
1	3.0
0.500	6.0
0.250	13.0
0.125	35.0
0.0625	85.0
none	100.

[1]Wallace, E. Lime sulphur as a summer spray. Cornell Agr. Expt. Sta. Bull. 289 1911.

[2]Morse, W. J., and Folsom, D. Apple spraying and dusting experiments 1918 to to 1924. Maine Agr. Expt. Sta. Bull. *325*: 1925.

[3]Maine Agr. Expt. Sta. Bull. 252.

[4]Wallace, E., Blodgett, F. M., and Hesler, L. R. Studies of the fungicidal value of lime-sulphur preparations. Cornell Agr. Expt. Sta. Bull. *290*: 1911.

[5]Reddick, D., and Wallace, E. On a laboratory method of determining the fungicidal value of a spray mixture or solution. Science N. S. 31: 798: 1910.

The results we have just given are in substantial agreement with those of previous workers.

The lead arsenate commonly met with on the market is predominately the acid arsenate of lead ($PbHAsO_4$) but a basic arsenate of lead ($Pb_4(PbOH(AsO_4)(AsO_4)_2H_2O)$ is also manufactured and used to some extent. The basic arsenate of lead is more stable than the acid arsenate[1], and we have also found that it is less toxic to the conidia of *Venturia inaequalis*. In our experiments we used the commercial acid and basic arsenates of lead manufactured by the General Chemical Company. The data presented in Table 2 show that per equivalent of arsenic the basic salt is less toxic than the acid salt at all strengths, the difference being very considerable at the concentration used in spraying, *i.e.*, 0.5 per cent. The acid arsenate of lead was completely toxic at a strength of 1 per cent, but the basic arsenate still permitted germination when used at a strength of 2 per cent.

TABLE 2.—*Relative toxicities of commercial acid and basic arsenates of lead to the conidia of Venturia inaequalis.*

AMOUNT OF LEAD ARSENATE USED	STRENGTH OF THE WASH IN METALLIC ARSENIC (As)		CONIDIA GERMINATION	
	Acid arsenate	Basic arsenate	Acid arsenate	Basic arsenate
Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*
2.000	0.3912	0.2864	0	7
1.000	0.1956	0.1432	0	35
0.500	0.0978	0.0716	3	22
0.250	0.0489	0.0358	12	43
0.125	0.0244	0.0179	70	67
0.062	0.0122	0.0089	66	65
none	0.0000	0.0000	79	79

In the graph (Fig. 1) the differences between the two salts are even more clearly brought out than in the table. The trend of the curve for the basic arsenate indicates that it would completely inhibit germination only at a high concentration if at all. The data obtained show clearly that even acid arsenate of lead could not be expected to adequately control apple scab since it is not invariably toxic at the concentration at which it is used in orchard spraying. In fact field experiments show, as we have seen, that whenever scab infestation is severe, *i.e.*, when more than 50 per cent of the apples on the non-sprayed trees are scabby, the protection afforded by lead arsenate becomes inadequate. The results secured by authors and which we summarize in Table 3 are in this respect conclusive.

[1]Bradley, C. E., and Tartar, H. V. Further studies of the reactions of lime-sulphur solution and alkali waters on lead arsenates. Journ. Ind. and Eng. Chem. *2*: 328: 1910.
Robinson, R. H., and Tartar, H. V. The arsenates of lead. Oregon Agr. Expt. Sta. Bull. *128*: 1915.

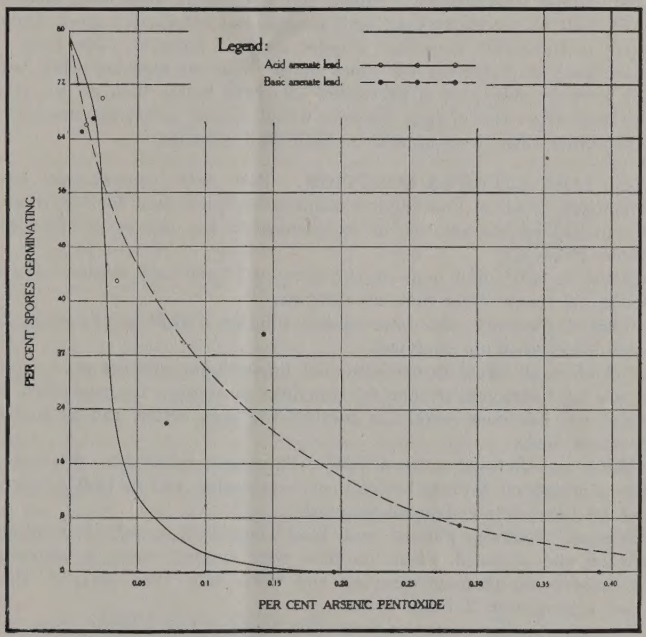

TABLE 3.—*Effect of intensity of scab infestation on the degree of control obtained by spraying with lead arsenate.*

SCABBY APPLES ON NON-SPRAYED TREES	PROTECTION AFFORDED BETTER THAN NO SPRAYING	AUTHORITY
Per cent		
5.00	12.0	Morse
38.81	24.0	Morse
39.00	2.5	Morse
83.00	1.7 and 1.9	Morse and Folsom
89.00	1.7	Pickett et al
89.36	1.3	Pickett et al
98.37	1.2	Morse

(b) **LIME ARSENATE.** Morse and Folsom[1] in 1918 used lime arsenate 2-50 in experiments on scab control and obtained a much higher degree of protection than that afforded by lead arsenate. The lime arsenate gave a protection 3.7 times better than no spraying while acid lead arsenate only gave a protection 1.9 times better than no spraying. The toxic properties of lime arsenate would appear to be, therefore, of a higher order than those of acid or basic lead arsenate.

(c) **LIME-SULPHUR SOLUTION.** Few field experiments have been made in which lime-sulphur solution has been used for the control of scab without the addition of an arsenical at any one or all the applications given.

Morse in 1917[2] used lime-sulphur solution 1.25-50 and obtained a protection 1.8 times better than no spraying.

Wallace[3] obtained with lime-sulphur solution 1.66-50 a protection 2.6 times better than no spraying.

Pickett et al[4] found in one case that lime-sulphur solution gave a protection 2.1 times greater than no spraying; in another the protection afforded was 5.6 times better; in another 3.4 times better, and in another 7.5 times better.

Morse and Folsom[5] using a 1.25-50 lime-sulphur solution, obtained in 1918 a protection 6 times better than no spraying and in 1919 a protection 1.6 times better than no spraying.

Bagenal, Goodwin, Salmon and Ware[6] employed a 1-29 lime-sulphur solution and obtained, when the trees were sprayed twice, a protection 1.3 times better than no spraying, and when they were sprayed three times a protection 2 times better.

The experiments quoted indicate that lime-sulphur solution gives better protection than arsenate of lead. Averaging the results from the experiments of Morse, Pickett et al, and Morse and Folsom in which comparative data are available, we find that when lead arsenate is used alone the protection afforded is 1.5 times better than no spraying and when lime-sulphur solution is used alone 3.8 times better. Lime-sulphur solution, therefore, gave on the average 2.5 times better control of scab than lead arsenate; but if we examine the data for the individual experiments which we have assembled in Table 4, it will be noted that the protection afforded by the lead arsenate did not vary widely, whereas in the case of the experiments with lime-sulphur solution we find two experiments giving protection differing but little from that afforded by lead arsenate and two experiments giving very similar and markedly better control than lead arsenate.

When lime-sulphur solution is sprayed upon a plant the wash decomposes rapidly. The sulphides disappear, and upon the foliage we find

[1]Loc. cit.
[2]Loc. cit. Bull. 271
[3]Loc. cit.
[4]Loc. cit.
[5]Loc. cit.
[6]Bagenal, N. B., Goodwin, W., Salmon, E. S., and Ware, W. M. The control of apple scab. Journ. Min. Ag. *33*: 38-49: 1926.

TABLE 4.—*Relative value of lead arsenate and lime-sulphur solution for the control of apple scab.*

SCABBY FRUIT	CONTROL OF SCAB WITH		AUTHORITY
	Lead arsenate	Lime-sulphur solution	
Per cent			
83.00	1.7 and 1.9	5.9	Morse and Folsom
89.00	1.7	2.1	Pickett et al
89.36	1.3	5.6	Pickett et al
98.37	1.2	1.8	Morse

sulphur, calcium thio-sulphate, calcium sulphate and calcium sulphite. The rate at which decomposition occurs depends upon the rapidity of drying and the humidity of the air to which the dried wash is exposed. When slides are sprayed with lime-sulphur solution and dried rapidly, *i.e.*, within 13 to 17 minutes, and then immediately stored on the one hand in dry air, that is in a desiccator over sulphuric acid, and on the other in an atmosphere saturated with water vapor, the sulphides remain unchanged indefinitely in the former case but rapidly disappear in the latter. We have obtained the following results when lime-sulphur solutions of different strengths were held in a moist chamber at room temperature.

	Sulphides absent after
Lime-sulphur solution 1-40	3½ hours
Lime-sulphur solution 1-20	4¾ hours
Lime-sulphur solution 1-10	5½ hours

The rate of decomposition of the sulphides is practically proportional to the concentration.

Under conditions favorable for the germination of the conidia of *Venturia inaequalis* lime-sulphur solution is only very slightly toxic at the strengths used in orchard spraying when sulphides can no longer be detected. We have obtained the following results.[1]:

	Germination per cent
Distilled water	75
Lime-sulphur solution 1-80	70
Lime-sulphur solution 1-40	70

In order for germination to be prevented the conidia must lie in contact with the wash in the dried state for a definite number of hours at a given temperature as has already been shown by one of us[2] before any deleterious effect upon germination will be noted when the spores are

[1]Vide also Doran, W. L., Laboratory studies of the toxicity of some sulphur fungicides. New Hampshire Agr. Expt. Sta. Tech. Bull. 19: 1922.
[2]Doran, W. L., loc. cit.

placed under favorable conditions for growth. We are, therefore, in a position to understand how the protection afforded by lime-sulphur solution should in some experiments of authors have proved much higher than in others.

(d) **LIME-SULPHUR SOLUTION AND LEAD ARSENATE.** Lime sulphur solution as used in spraying for apple scab has lead arsenate added to it at two or more of the sprayings usually given, and the protection obtained has been of such a high order that this fungicide-insecticide combination has been very generally adopted in spraying schedules. The control obtained, as will be seen from the data collected in Table 5, shows that better protection is afforded by lime-sulphur solution and lead arsenate than is afforded by lime-sulphur solution alone and fully warrants the feeling pervading the literature that the toxic properties of lime-sulphur solution are increased by the addition of lead arsenate.

TABLE 5.—*Relative value of lime-sulphur solution and lime-sulphur solution and lead arsenate for the control of apple scab.*

SCABBY APPLES	CONTROL OF SCAB WITH		AUTHORITY
	Lime Sulphur solution	Lime sulphur solution and lead arsenate*	
Per cent	*Times better than no spraying*		
30.00	7.50	15.0	Pickett et al
72.80	2.0	2.5	Bagenal et al
73.00	3.4	5.6	Pickett et al
79.40	2.6	7.2	Wallace
83.00	6.0	3.8	Morse and Folsom
89.00	2.1	3.5	Pickett et al
89.36	5.6	9.3	Pickett et al
98.00	1.5	2.9	Morse and Folsom

*When a selection has been possible we give the data for lime-sulphur solution and acid arsenate of lead.

In the case of lead arsenate we found that laboratory tests showed that this substance was not completely toxic at the strength used in orchard spraying and in the case of lime-sulphur solution that the toxicity of the wash depended on the temperature preceding the period of spore germination; one might obtain complete protection or one might secure no protection at all. The laboratory experiments confirmed the conclusions that would be drawn from the field experiments. Laboratory tests made with lime-sulphur solution and arsenate of lead are equally confirmatory.

[1]Loc. cit.

Wallace, Blodgett and Hesler[1] found that the addition of arsenate of lead to lime-sulphur solution very greatly increased the toxicity of the latter. The results they secured were quite striking as will be seen from a summary of their data which we present in Table 6.

TABLE 6.—*Effect of an addition of lead arsenate on the toxicity of lime-sulphur solution to the spores of Venturia inaequalis.*

SPRAY USED	DILUTION OF LIME-SULPHUR SOLUTION AND RELATIVE GERMINATION				
	1-100	1-50	1-30	1-20	1-10
Lime-sulphur	56.12	18.73	18.70	9.37	Trace
Lime-sulphur and lead arsenate	1.39	1.05	0.00	0.00	.....
None	100	100	100	100	100

The results we have secured also show that the addition of lead arsenate greatly increases the toxicity of lime-sulphur solution as will be seen from the following figures:

	Spore germination
Witness	75 per cent
Lime-sulphur solution 1-80	70 per cent
Lime-sulphur solution 1-80 and lead arsenate 0.37 per cent	5 per cent
Lime-sulphur solution 1-40	70 per cent
Lime-sulphur solution 1-40 and lead arsenate 0.37 per cent	3 per cent
Lime-sulphur solution 1-20	36 per cent
Lime-sulphur solution 1-20 and lead arsenate 0.37 per cent	0.00 per cent

In our experiments it will be noted lime-sulphur solution was only very feebly toxic at dilutions of 1-80 and 1-40, and the effect produced at a dilution of 1-20 was not pronounced so that the toxicity produced by the addition of lead arsenate is if anything even more forcibly brought out than in the experiments of Wallace, Blodgett and Hesler, in which it is somewhat masked owing to the toxicity exhibited by the lime-sulphur solution itself.

Bradley and Tartar[2] and several other workers have shown that the decomposition of lime-sulphur solution by acid arsenate of lead is accompanied by the appearance of soluble arsenic in solution in amount sufficient for one to suspect that the increased toxicity resulting from the addition of lead arsenate to lime-sulphur solution would be due to soluble arsenic. We have, therefore, studied the effect of adding arsenious oxide previously dissolved in water to lime-sulphur solution. The results obtained were as follows:

[1]Loc. cit.
[2]Loc. cit.

	Spore germination
Lime-sulphur solution 1-40 + .02 per cent arsenious oxide	0 per cent
Lime-sulphur solution 1-40 + .01 per cent arsenious oxide	2 per cent
Lime-sulphur solution 1-40 + .005 per cent arsenious oxide	10 per cent
Lime-sulphur solution 1-40 + .0025 per cent arsenious oxide	10 per cent
Lime-sulphur solution 1-40 + .0012 per cent arsenious oxide	22 per cent
Lime-sulphur solution 1-40	70 per cent
Lime-sulphur solution Witness	75 per cent

The increased toxicity due to the addition of arsenious oxide is very marked and shows clearly that the appearance of even a small amount of soluble arsenic in solution is sufficient to account for the greater toxicity of lime-sulphur solution to which an arsenate of lead has been added.

Bradley and Tartar[1] have shown that under comparative conditions the amount of arsenic appearing in solution when acid arsenate of lead is added to lime-sulphur solution is eight times the amount found when basic arsenate of lead is used. They give the following figures:

	Arsenic oxide in solution
Lime-sulphur solution + acid arsenate lead	.095 per cent
Lime-sulphur solution + basic arsenate lead	.012 per cent

It will be noted that in the case of the basic arsenate of lead the amount of soluble arsenic in solution was not materially different from that obtained by the addition of .01 per cent arsenious oxide. We have seen that basic arsenate of lead is considerably less toxic than acid arsenate of lead but from the fact that it does yield soluble arsenic in toxic amount when added to lime-sulphur solution we should find that the control of scab obtained in orchard spraying was not widely different from that secured by the use of acid arsenate of lead. In fact the few comparative experiments that have been made show this. Pickett et al[2] obtained the following results:

	Per cent scabby fruit	
	A	B
Non-sprayed trees	73.0	30.0
Lime-sulphur solution + acid arsenate lead	13.0	2.0
Lime-sulphur solution + basic arsenate lead	32.0	3.0

Morse and Folsom[3] obtained the following results:

	Per cent scabby fruit
Non-sprayed trees	83.0
Lime-sulphur + acid arsenate lead	22.0
Lime-sulphur + basic arsenate lead	19.0

[1]Loc. cit.
[2]Loc. cit.
[3]Loc. cit.

(e) **LIME-SULPHUR SOLUTION PLUS LIME ARSENATE.** Cook and McIndoo[1] have shown that when lime arsenate is added to a lime-sulphur solution there is no reaction and the amount of arsenic found in solution is the amount originally present in the arsenate. It has also been shown by Robinson[2] that di-calcium arsenate ($CaHAsO_4(H_2O)$) and tri-calcium arsenate (Ca_3 (As O_4) $_2$) behave similarly when added to lime-sulphur solution. The di-calcium arsenate is more soluble in water than tri-calcium arsenate, and the solubility of both is increased by the presence of carbon dioxide. Toxicity tests that we have made show, as will be seen from a consideration of the data presented in Table 7, that

TABLE 7.—*Effect of an addition of lime arsenate on the toxicity of lime-sulphur solution.*

WASH USED	SPORE GERMINATION SOLUTION DILUTED	
	1-80	1-40
	Per cent	*Per cent*
Lime-sulphur solution	70	70
Lime-sulphur solution + lime arsenate 0.25%	45	40

the addition of lime arsenate to lime-sulphur solution increases the toxicity of the latter between 1.56 and 1.75 times; on the other hand, the addition of lead arsenate as we have seen increases it between 14 and 23 times. The toxicity studies confirm the results of chemical analysis. The toxicity of lime-sulphur solution plus lime arsenate is far below that of lime-sulphur solution plus .0012 per cent arsenious oxide. It is to be noted, however, that in our experiments the lime-sulphur solution and lime arsenate was sprayed upon the slides, allowed to dry spontaneously and then stored in a dry place until used. The slides were not subject to periodic wetting and drying such as would occur in nature so that we did not secure any benefit that might arise due to the liberation of soluble arsenic on weathering. That weathering must increase the toxicity of the combined spray would appear undoubted since the control of apple scab in orchard spraying obtained with it is eminently satisfactory.

Sanders[3] has shown that the protection afforded by lime-sulphur solution and lime arsenate is as good or better than that afforded by lime-sulphur solution and lead arsenate. Morse and Folsom[4] in 1918 obtained the following results:

	Scabby apples
Non-sprayed trees	83 per cent
Lime-sulphur + lime arsenate	8 per cent
Lime-sulphur + acid lead arsenate	22 per cent

[1]Cook, F. C., and McIndoo, N. E. Chemical, physical and insecticidal properties of arsenicals. U. S. Dept. Agr. Bull. 1147: 1923.
[2]Robinson, R. H. The calcium arsenates. Oregon Agr. Expt. Sta. Bull. 131: 1918
[3]Sanders, G. E. Arsenate of lead vs. arsenate of lime. Proc. Ent. Soc. Nova Scotia 1916: 40-45; 1917.
[4]Loc. cit.

and in 1919 the following:

	Scabby apples
Non-sprayed trees	98 per cent
Lime-sulphur + lime arsenate....	33 per cent
Lime-sulphur + acid lead arsenate	33 per cent

For a number of years we have been using for the control of scab on McIntosh apples lime-sulphur solution 1-50 plus 1.5 lbs. lime arsenate per 50 gallons for the pre-pink and calyx sprays, and lime-sulphur 1-50 for the pink spray and for the spray applied 14 days after the calyx application when four treatments were given. In Table 8 we give some of the results secured. In none of the experiments was there as much as 4 per cent of the scabby apples rejected from Grade A on account of size of or aggregate size of scab lesions, and no argument is necessary to convince the most skeptical that the control obtained has been eminently satisfactory.

TABLE 8.—*Effect of using lime arsenate on the control of scab by lime-sulphur solution.*

TREES	PERCENT SCABBY APPLES ON TREES SPRAYED IN				
	1923*	1924*	1925	1926	1927
Sprayed.....	4.05	0.63	5.0	0.0	27.1
Not sprayed.....	72.6	10.5	...	...	86.8

*Trees were sprayed four times.

We have studied lead arsenate, lime arsenate, lime sulphur solution, and lime-sulphur solution plus the arsenicals mentioned from the point of view of apple scab control. There remain to be considered the effects of these several substances upon the tree.

II

(a) ARSENATE OF LEAD. Arsenate of lead may be used upon the apple and causes practically no russeting of the fruit. Morse in 1916[1] found that the amount of russeting developing on the fruit of trees sprayed with 2-50 arsenate of lead was 1.79 times greater than on non-sprayed trees. In 1917, on the other hand, the trees sprayed with 2-50 acid arsenate of lead produced fewer russeted fruit than the non-sprayed trees, there being only 0.1 times as many russeted apples on the sprayed as on the non-sprayed trees.

Morse and Folsom[2], in an experiment in which they used in one case acid arsenate of lead and in the other basic arsenate of lead, obtained the following results:

[1]Loc. cit.
[2]Loc. cit.

	Russeted fruit
Trees sprayed with 2-50 acid arsenate lead.....	1 per cent
Trees sprayed with 2-50 basic arsenate lead.....	1 per cent
Trees not sprayed.....	1 per cent

Robinson and Tartar[1] sprayed apples growing in the Willamette Valley, Oregon, with acid and basic arsenates of lead using 2, 4 and 8 lbs. of the salts in paste form per 100 gallons of spray and no injury was produced by either at the strengths used.

Pickett et al[2] obtained 1 per cent russeted fruit on trees sprayed with lead arsenate and no russeting on non-sprayed trees in one instance. In another the non-sprayed trees produced 15.27 per cent russeted fruit, the trees sprayed with lead arsenate 5.6 per cent.

(b) **LIME ARSENATE.** The concensus of opinion is that lime arsenate cannot be safely used alone. Sanders[3] states that lime arsenate when used alone causes severe burning, and Lovett[4] is of the opinion that it cannot be safely used in orchard spraying. Morse and Folsom found 1 per cent russeted fruit on non-sprayed trees, 2 per cent russeted fruit and marked foliage injury on trees sprayed with 2-50 lime arsenate. Cook and McIndoo[5], however, believe that lime arsenate as soon as processes of manufacture have been standardized will be just as harmless to plants as lead arsenate now is.

(c) **LIME-SULPHUR SOLUTION.** Morse[6] in 1917 used 1.25-50 lime-sulphur solution and found that spraying increased the russeting 1.98 times; there were 14.56 per cent blemished apples in the case of the sprayed trees and 7.36 per cent in the case of the non-sprayed trees. Pickett el al[7] obtained in two instances no increased russeting as a result of spraying with lime-sulphur solution and in a third 9.9 per cent russeted fruit on the sprayed trees and 15.27 on the non-sprayed trees. Morse and Folsom[8] obtained 7 per cent russeting on sprayed trees and 1 per cent on non-sprayed trees.

It is apparent, therefore, that lime-sulphur solution causes no material injury to the apple.

(d) **LIME-SULPHUR SOLUTION AND LEAD ARSENATE.** We have already seen that when arsenate of lead is added to lime-sulphur solution double decomposition occurs, arsenic appears in solution and the fungicidal properties of the latter are increased. Lime-sulphur solution and arsenate of lead in combination are very commonly injurious to the apple. Either alone may be safely used.

[1]Loc cit.
[2]Loc. cit.
[3]Loc. cit.
[4]Lovett, A. L. Insecticide investigations. Oregon Agr. Expt. Bull. 179; 1920
[5]Loc. cit.
[6]Loc. cit. Bull. 271.
[7]Loc. cit.
[8]Loc. cit.

Morse[1] in 1916 found that when 1.25-50 lime-sulphur solution plus 1 lb. acid arsenate of lead was used, there was 66.69 per cent russeted apples on the sprayed trees as against 20.57 per cent on the non-sprayed; but in 1917 the russeting on the sprayed trees was about one-fourth of that on the non-sprayed trees.

Morse and Folsom[2] in 1918 obtained on the average 1.25 per cent russeted fruit on trees sprayed with lime-sulphur solution plus lead arsenate but only 1 per cent russeted fruit on the non-sprayed trees; in 1919 there was no russeted fruit on the non-sprayed trees and less than 0.25 per cent on the sprayed trees.

The experiments of Pickett et al[3] show that while the per cent of russeted fruit produced by trees sprayed with lime-sulphur solution to which lead arsenate has been added is very variable it is usually greater than that produced on the fruit of non-sprayed trees from natural causes.

(e) LIME-SULPHUR SOLUTION PLUS LIME ARSENATE. Morse[4] in 1916 used 1.25-50 lime-sulphur solution plus 1 lb. calcium arsenate and obtained little or no increase of russet due to the wash. The sprayed trees yielded 22.75 per cent russeted fruit, the non-sprayed trees 20.57 per cent. Morse and Folsom[5] in 1918 found 9 per cent russeted fruit on the trees sprayed with 1,25-50 lime sulphur solution plus 1 lb. calcium arsenate, and 1 per cent russeted apples on the non-sprayed trees, and in 1919 less than 0.25 per cent russeted fruit on the sprayed trees and none on the non-sprayed trees. The foliage was not injured either year.

In our experiments we have secured at most but the faintest of russet on the fruit, and no foliage injury following the use of lime-sulphur solution 1-50 plus 1½ lbs. calcium arsenate[6] per 50 gallons for the pre-pink and calyx sprays.

It will be noticed that the amount of lime arsenate we used is 50 per cent stronger than that used by Morse and Folsom or recommended for general use by Holland, Bourne and Anderson[7] so that it is altogether probable that, were the smaller quantity of lime arsenate used, the amount of injury produced would be quite negligible since we obtained so little russeting on the fruit and no foliage injury with a dose higher than entomologists recommend.

In 1923 the maximum injury produced on the fruit was a smooth, net-like russet. Most grading laws provide that in first grade fruit otherwise perfect, not more than 25 percent of the surface may be injured by this type of russet. The percent of fruit falling out of grade A on account of injury of this type was small. In 1924 the bloom on the sprayed fruit was better than on the non-sprayed fruit and the injury due to the spraying was so faint as to be hardly visible. In 1925, 1926 and 1927 no

[1]Loc cit.
[2]Loc. cit.
[3]Loc. cit.
[4]Loc. cit.
[5]Loc. cit.
[6]We have used commercial tri-calcium manufactured by Riches, Piver and Co. and Chipman Chemical Engineering Co.
[7]Holland E. B., Bourne, A. I., and Anderson, P. T. Insectfcides and Fungicides, Mass. Agr. Expt. Sta. Bull. 201, 1921.

injury was noted at all and the appearance of the fruit was all that could be desired.

The evidence presented shows that lime arsenate may be used in place of lead arsenate in orchard spraying and that its use is in no respect prejudicial. Scab control when lime arsenate is used is as satisfactory as when lead arsenate is employed, and fruit russeting is less rather than more conspicuous.

SUMMARY

I. Lead arsenate is uninjurious to the apple but does not control scab satisfactorily.

II. A judgment cannot definitely be entered regarding lime arsenate.

III. Lime-sulphur solution controls scab under conditions favorable for its action satisfactorily.

IV. Lime-sulphur solution and lead arsenate give satisfactory control of scab but cause more or less russeting of the fruit.

V. Lime-sulphur solution and lime arsenate satisfactorily control scab and russet the fruit but little if at all.